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Technical Lesson 64

SHORT WAVE (HIGH FREQUENCY) RECEIVERS.

The distances which high frequencies (short waves) carry when using relatively low power are almost unbelievable. Even during the daylight hours when transmission on long waves is not ordinarily good, and despite prevailing weather conditions, we know that the high frequencies will provide reliable long-distance communication service. A very notable and valuable characteristic experienced in short wave reception is the almost complete freedom from interference set up by static. The same is not true when working on the higher wavelengths. The long-distance value of these short waves, the relatively low cost of transmitting equipment and maintenance, and the use of very simple receivers all contribute toward a new interest in radio transmission and reception that is at least equal to and perhaps greater than that which most of us experienced during the pioneer days of broadcasting. In order that we may have a well built structure upon which to base our future work in this field it is necessary that we not only study about the equipment and circuits themselves but we must also inform ourselves about the peculiarities of short wave propagation and their effectiveness. There is a generous amount of information to be had on this subject supplied from different sources, as for instance the data furnished by the U.S. Army, the U.S. Navy, the Naval Research Laboratory, the American Radio Relay League, the large commercial radio companies and the contributions of thousands of owners of amateur short wave stations.

In general the tuned circuits of short wave receiving sets are quite similar to the tuned circuits of short wave transmitters. Tuning is accomplished in either class of apparatus by altering the values of inductance and capacitance until the desired circuit constants are found at which radio oscillations of a particular frequency will circulate with maximum effectiveness through the circuits. Remember, all of our oscillatory circuits have a definite amount of inductance and capacity, hence, they tune to a certain frequency.

Some short wave transmitters, depending of course upon the service they render, use only one wavelength. Consequently after a circuit has once been calibrated and checked by a wavemeter measurement, then usually the transmitter requires no further adjustment unless it wavers off its assigned frequency for any cause. If more than one wavelength is assigned to the transmitter, as would be the case in commercial work, then suitable clips and switching arrangements are provided to permit an instant change from one wave to another.

On the other hand, a receiving set must always permit quick and easy tuning over a wide band of frequencies. To meet the latter requirements a short wave receiver must be supplied with several plug-in or interchangeable inductances of various sizes, each coil being designed to encompass a limited frequency range. Also, there must be sufficient overlapping of frequencies at the extreme upper and lower limits of different inductances to provide a

progressive change in frequency without a break or interruption within the scope of the receiver.

A regenerative circuit is essential in short wave work. Two variable condensers are usually embodied in the design of present day short wave receivers; the purpose of one condenser is to alter the capacitance of the tuned circuit and the other to regulate the amount of regeneration, i.e., to control the amount of feed-back voltage supplied to the grid input circuit from the plate circuit. It is to be especially noted that the wavelength range we can cover with a certain coil depends mainly upon the maximum capacity of the tuning condenser shunted across it.

We find that coil-condenser combinations of the plug-in type are coming into more general use; they consist of a separate tuning condenser employed with each inductance in the set. This feature makes it possible, when tuning, to utilize the entire dial scale for the frequency band covered by each inductance used. The practicability of using plug-in tuning condensers as well as plug-in inductances for receivers which at times must work in odd widths of the various frequency bands is quite obvious. This class of service demands that stations operating, let us say, several hundred cycles from each other must be separated in order to individually copy their signals. So, if we use a coil-condenser combination we can make each band spread across the full range of the dial. Any one who is familiar with tuning, in general, knows that when a wavelength band is cramped within a short radius on the dial, using only a limited number of the available divisions, it simply lessens selectivity even when a precise vernier control is used. In other words, the value of this method rests in the fact that it gives full scale coverage for any band according to the inductance used, as we have just stated. It is not to be understood that a plug-in condenser is always necessary in a circuit arrangement to give satisfactory results; also the use of the last 10 divisions, or so, on the upper and lower limits of the condenser dial scale is unnecessary.

Other requirements of short wave receivers in addition to selectiveness are the avoidance of hand-capacity effects, smooth regeneration control without appreciable variation of the tuning, and freedom from so-called "dead spots" where the circuit stops oscillating and the signal is lost. The trend of short wave receiver design is toward the development of efficient r.f. amplifiers that will operate with stability, meaning that the amplifiers will not break into self-oscillation thus causing erratic results. The screen grid tube, type 222 (four element tube) is especially suited for use as an r.f. amplifier because of its inherent quality of cancelling the effect of inter-electrode (grid to plate) capacity. It must be said, however, that r.f. amplification in a short wave receiver does not always give a perceptible improvement in the distance covered. Moreover, an additional tuning control might be required for the r.f. amplifier circuit. An operator might find extra dials very inconvenient especially when attempting to hold a distant transmitter whose frequency is wavering (or wobbling as we more commonly refer to such a condition). It frequently happens in practice that an operator is required to tune with one hand and copy a message with the other. On all but very distant stations, the receiver should be tuned by simply turning one tuning control. On very weak stations it might be found necessary to adjust the coupling between the antenna and grid coils to obtain maximum signal strength. For these

reasons considerable attention is always given to the receiver design to make it simple in operation. A one or two stage audio-frequency amplifier may be used with a receiver of any type to build up weak signals. The transformers in such an audio system should provide uniform amplification of all frequencies in the audible range but they must act to suppress high frequencies or losses would be sure to occur. In referring to the effectiveness of a transformer in readily passing a certain band of frequencies above or below the band we would simply say, "the transformer provides a sharp cut-off at both ends."

And now let us proceed to a brief discussion on the use of the condenser previously mentioned for regulating regeneration. By the correct adjustment of this condenser, known as a "throttle condenser", the receiving circuit may at one time be placed in a regenerative condition for the reception and amplification of a modulated signal, as for instance ACCW, (Refer to figure 9, Lesson 60 which shows an ACCW curve), or radio telephone transmission (broadcast). Then by gradually increasing regeneration through careful manipulation of the throttle condenser the radio-frequency feed-back voltage may be made sufficiently strong to cause the circuit to slide into oscillation and the set would then be capable of receiving continuous r.f. oscillations (C.W.). The point at which oscillations begin is evidenced by a noticeable click in the phones or a simple test for oscillation is to touch the condenser stator plate with the finger; forming the contact should produce a click. You will recall from your early lessons on "Regeneration" that when a receiver is generating r.f. oscillations within its own circuits and at the same time it receives a C.W. signal it will set up an audible beat current capable of actuating the telephone diaphragms. This production of a beat current is the result of our receiver oscillations combining with the incoming signal oscillations, providing of course that their frequency difference is in the audible ranges. Although two beat currents, one higher in frequency than the other, are actually produced by this interaction of high-frequency oscillations, yet by intelligent use of the controls we can tune our circuit to respond to either audio-frequency. Naturally we would tune to that beat frequency which provided the best readable note. In any circuit which is designed to generate the local radio-frequency and produce beats in this manner we have the heterodyne method of continuous wave reception.

Explaining briefly a major requirement of a short wave receiver we could say then that for phone or modulated CW work the set should just be outside the oscillating condition where maximum amplification is obtained, and for CW work the set should be just inside the oscillating point where stability of operation is assured.

The schematic diagrams in Figures 1, 2 and 3 show in a general way three methods for controlling regeneration in the detector circuit. We can easily recognize the circuit in Figure 1 as the familiar three-circuit tuner with the tickler coil controlling regeneration. A system of this type is quite impractical in short wave work because of the marked changes effected in the tuned grid circuit whenever the tickler coil is adjusted. The circuits in Figures 2 and 3 both make use of a fixed tickler with regeneration governed by a variable condenser of small capacity. This is the throttle condenser, marked CT, shown connected between the plate of the detector and the tuned oscillatory circuit. The circuit in Figure 2 is known as the shunt (parallel) plate feed

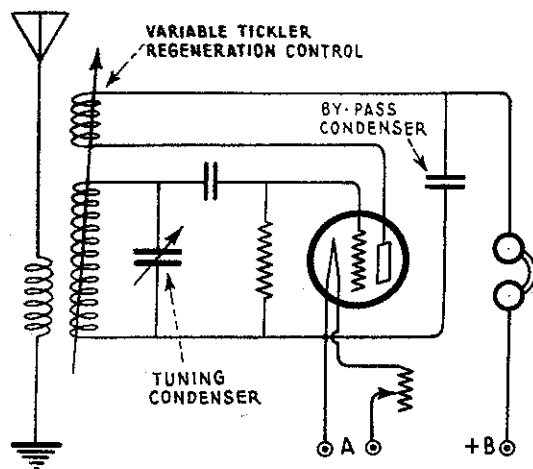


Figure 1

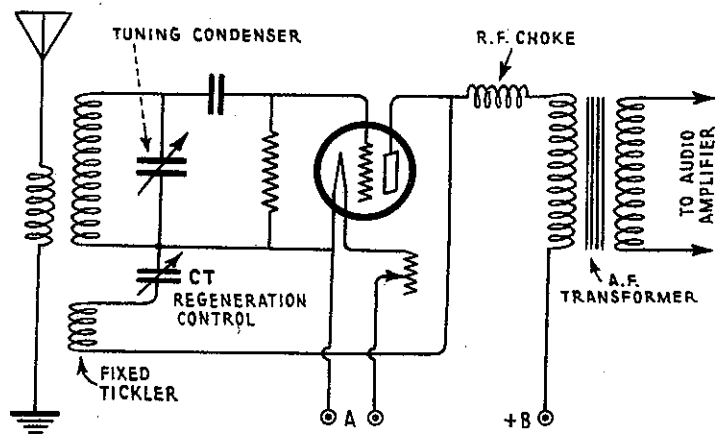


Figure 2

type and is perhaps the one most widely used for the reception of high frequencies. In Figure 3 we have the series plate feed type. There is a circuit in popular use which is quite similar in general arrangement to the one shown in Figure 1. The essential difference is that the tickler coil is fixed (not variable as shown in this diagram) and a variable resistance is inserted in series with the detector plate lead. Other means for controlling regeneration are embodied in the design of short wave sets, as for example by varying the heating current supplied to the filament. The desired changes in the filament terminal voltage are made by adjusting the filament rheostat. Or still another method is one which incorporates both a variable resistance in the plate lead and the throttle condenser connected in the circuit in the usual manner. This arrangement provides a combined resistance and capacity control of regeneration.

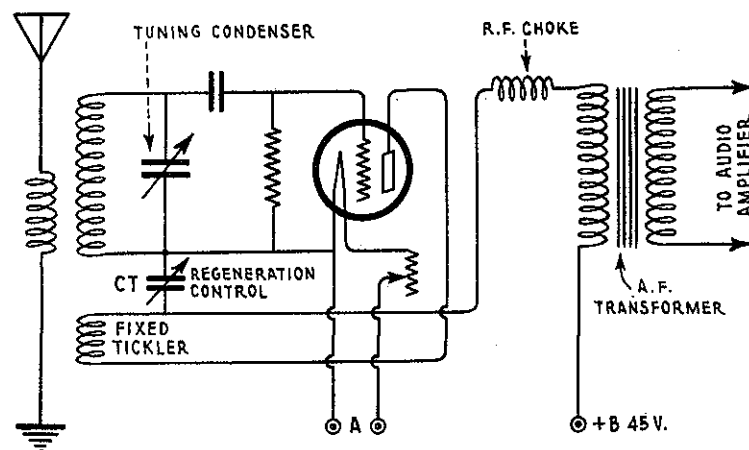


Figure 3

A short wave receiver must tune more sharply than would be necessary in the case of sets used exclusively for broadcast reception. If a circuit does not tune sharply it is only natural to expect that when a certain station is being worked, then at the same time other stations will be heard, thus causing a

more or less strong background of interference. Under some conditions a receiver may be de-tuned slightly when interference is experienced and although this procedure will result in a small sacrifice in signal volume on the desired station yet the reduction in interference may in many cases allow a message to be easily copied by the operator.

It is seen that in short wave work we are interested both in the design and operation of a set in order to obtain maximum transfer of radio signal energy from the antenna system at one frequency and to place the set into a state of oscillation or regenerative amplification, at will, as determined by the character of the signals received.

The question is often asked "Where is the line of division between the short waves and the long waves?" To set a definite line of demarkation, insofar as we know, has not been attempted, it being generally understood that the short waves are those in the order of 200 meters and below, reaching down to still another range commonly known as the "ultra-short" waves, these latter being arbitrarily classified as waves of 5 meters and less.

Long waves, then, may be considered as those extending from about 200 meters to approximately 24,000 meters. The very long waves are in use at the present time in trans-oceanic commercial work. The ultra-short waves have been utilized to a limited extent only within recent months. It is not to be understood that their use has reached a stage of perfected development. Extensive research and experimentation are now being conducted by the engineers of the government and commercial organizations to make the ultra-short waves useful for radio service. It seems almost beyond a doubt that the effectiveness of these waves will soon solve the problem of consistent long distance communication, day or night, and regardless of seasons or weather conditions. In order to give you an idea of the extraordinary high frequencies involved in the lowest wavelengths let us add that scientific investigators believe the ultra-short wave spectrum to be close to and merging into the heat wavelengths. This suggestion of the close proximity of radio waves and heat waves might have some influence upon observed phenomenon in regard to the concentration of radio energy, as for example, in "beam transmission". Here radio signals are directed in a narrow path, only a few degrees wide, toward a certain receiving station thousands of miles distant. A simple means for comparing different forms of energy when concentrated is found in the heat beam thrown out from the polished copper reflector of a type of electric house heater with which most of us are familiar. Present observations indicate that the possibilities of utilizing the entire short wave band (or high-frequency spectrum, which means the same thing) are limitless. Accordingly, as new transmissions are effected there will be a steady development in short wave receiving equipment to keep abreast of the demands.

In present day radio parlance it is customary to speak of short wavelengths in their equivalent of kilocycles, or we simply say Kc. (Kc being the abbreviation for kilocycles). The use of the unit, the meter (or wavelength in meters) is not now generally preferred. Often we find it more convenient to use a sub-multiple of the kilocycle, the megacycle. One megacycle equals 1,000,000 cycles. Simple calculations can be made to translate wavelength to frequency and vice versa by applying the well known wavelength formula.

Where wavelength (λ lambda) = $\frac{300,000,000 \text{ meters (velocity)}}{\text{frequency in cycles}}$

It is a very easy matter to change frequency when expressed in cycles to either kilocycles or megacycles. In fact it can be done without resorting to the use of pencil and paper. For example:

30,000,000 cycles = 30,000 Kilocycles = 30 megacycles.
10,000,000 cycles = 10,000 Kilocycles = 10 megacycles.

The following paragraphs will be devoted to a consideration of the effectiveness of short waves. It is evident in practice that the short waves do reach out and cover tremendous distances, but their great practical advantage is their effectiveness in establishing consistent communication during the daylight when communication would ordinarily be difficult when working on the long waves.

A glance at the following tabulation will convince anyone of the remarkable persistence of the high-frequencies in getting signals through to their destination during the daylight hours. We generally speak of the communication range as either "day miles" or "night miles" as the case may be. This performance data, presented before the Institute of Radio Engineers by Captain S.C. Hooper, U. S. N., gives the average results over a period of many months of investigation under all sorts of climatic conditions.

Frequency Band Kilocycles	Communication Range Average Distance	
	Day-Miles	Night-Miles
1500-2000	100	250
2000-2250	125	300
2250-2750	150	500
2750-2850	150	550
2850-3500	250	600
3500-4000	300	1000
4000-5500	450	2500
5500-5700	500	3500
5700-6000	550	4000
6000-6150	600	5000 +
6150-6675	800	"
6675-7300	1000	"
7300-8550	1200	"
8550-8950	1500	"
8950-9500	1800	"

Although the peculiarities of the high frequencies are not fully understood yet there has been sufficient handling of traffic in this field to enable station engineers to draw up working schedules which indicate just what frequencies are most likely to reach a distant receiver at certain hours. The communication range on short waves changes rapidly and it is not an uncommon occurrence to get signals through at a certain hour at a particular

frequency and have them fade out entirely the following hour. Such a working schedule is simply an accurate record of transmission phenomenon giving the most effective frequency to be selected for stated hours. For instance, let us suppose that a sending station is working a distant receiver on about 16,000 kc. at 2 A.M. with a strong signal. Now if messages are still on file which must be transmitted the following hour, then both stations will automatically shift to some other frequency, perhaps 7,300 kc. conforming to the schedule.

Short waves become reflected, refracted and polarized in transmission resulting in what is commonly known as the skip distance effect. The peculiar behavior of the high-frequencies is accounted for by the Heaviside Layer theory, or it is more inclusive to say Heaviside-Kennelly theory, named after the investigators who developed the theory of ionization of the upper atmosphere by the action of the sun's rays. This theory has already been explained in our lesson on "Short Wave Transmitters".

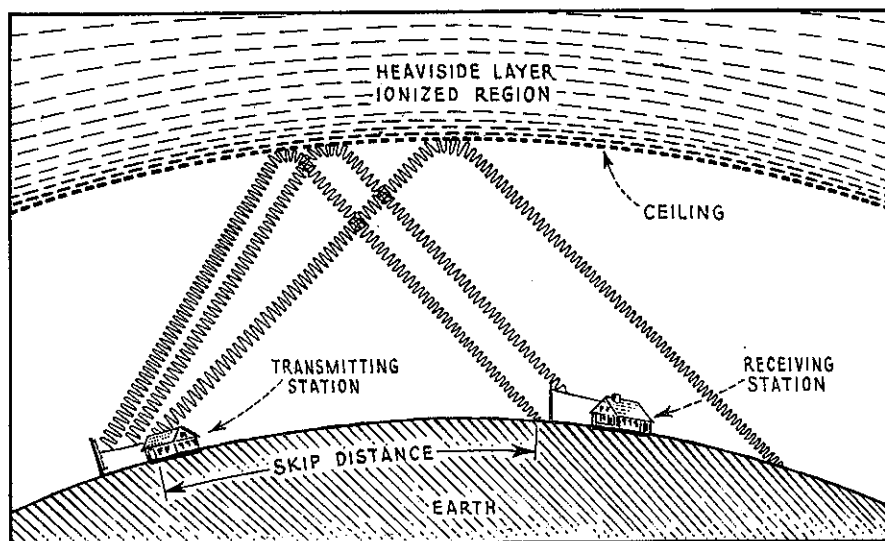


Figure 4

The drawing in Figure 4 illustrates the "Skipped distance" features. This is a simple means of showing the various possible paths of the short waves as they depart from the transmitting antenna, reach the ionized layer, and are reflected to the earth at varying distances. Frequencies above 6,000 kc. have a silent zone due to the "skipping" of the wave, at distances varying up to hundreds of miles in the daytime and even thousands of miles at night, depending on the frequency from the transmitting station. Because of the uncertain characteristics which the high frequencies are prone to display the values given in the table are subject to deviation. The seasons, summer and winter, day and night, and differences in the height of the Heaviside layer all have their individual effects on transmission distance. The curves in Figure 5 illustrate this. These curves are an approximation of the effective mid-day sky wave for all seasons, a night sky wave for all seasons, a skip distance curve for summer mid-day and winter midnight, and an all season ground wave for night and day. Curve 1 shows the approximate distance versus fre-

quency for an all season mid-day sky wave. Captain Hooper explained the use of the curves as follows. For example: Given a distance 2200 miles find the frequency to produce a good readable signal at the receiving station. Vertically up from 2200 miles to Curve 1 and horizontally to the left, read 11,400 Kc. Given a certain frequency the distance will be found by the reverse process. The frequency and the distance are approximately accurate when in an east-west direction, but the frequency and distance for north and south transmission may vary greatly from these figures.

The approximate distance versus frequency for the night sky wave at all seasons is illustrated by Curve 2. The curve is read in the same manner as explained above. To produce a good readable signal at a receiving station 2200 miles away when both the receiving and transmitting stations are in darkness, it is found that approximately 6000 kc. will suffice. Also it is probable that any frequency between Curve 1 and Curve 2 at 2200 miles will suffice and the choice of frequency depends upon the experiment and the time of day. Greater distances are covered by the lower frequencies at night as shown by this curve. The frequency and distance for north and south transmission may vary somewhat from the above.

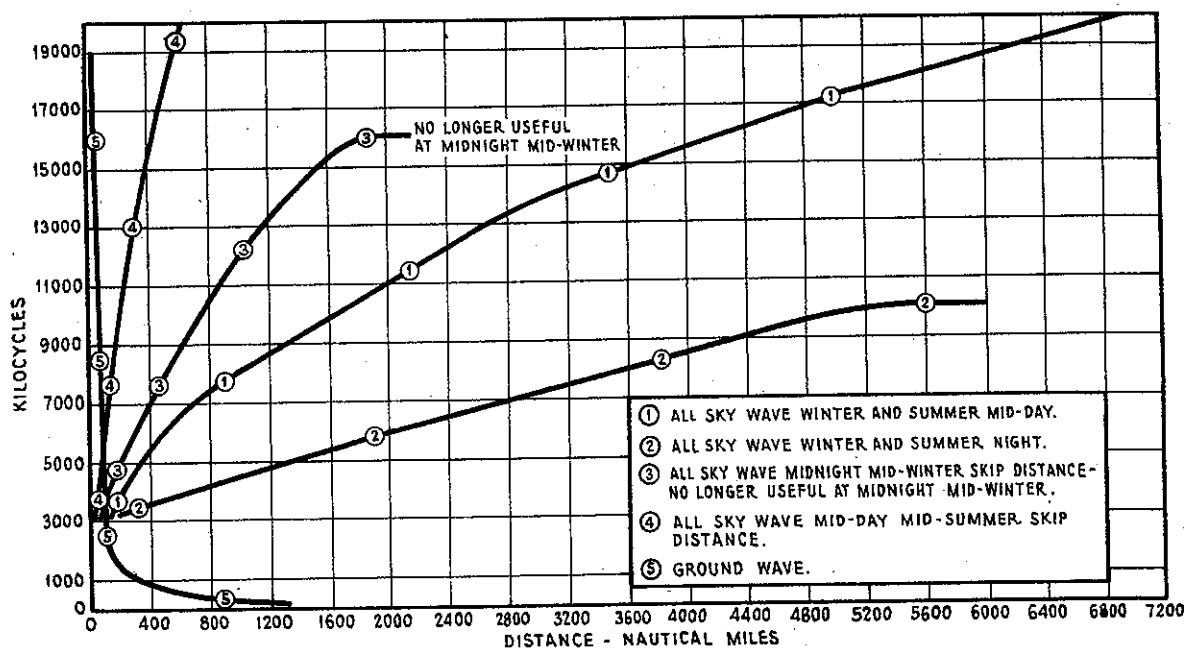


Figure 5

An approximation of skip distance versus frequency for midnight mid-winter is given in Curve 3. The skip distance is measured horizontally to the right from Curve 5. The skip distance at any particular time of day or year may vary between the horizontal on Curves 3 and 4.

Skip distance versus frequency for mid-day mid-summer is shown in Curve 4. The skip distance is measured horizontally to the right from Curve 5. Curves 3 and 4 are read in the same manner as described above. The last curve, No. 5, is an approximation of distance versus frequency of the ground at all seasons for night or day. The curve is to all intents and purposes a ground

wave suitable for radio compass work. Night effect may be expected. This curve as shown is good for approximate day and night transmission. An increase of power may be required of the lower frequencies for the required distance.

Short Wave Receiver. A photograph of a short wave receiver appears in Figure 6. We reproduce this photograph through the courtesy of "QST". The inductances are fitted with plugs which provide electrical contact and also serve as a means for mounting them in the sockets. A short wave receiver is supplied with several sets of inductances of different sizes and by interchanging coils the receiver can be made to cover a very wide frequency band. Although the frequency range of each set of coils is large yet the wavelength band is small, as may be ascertained by reference to a frequency-wavelength conversion chart.

The coils and other circuit elements require special care in their design and assembly in order that the receiver will behave in a consistent manner throughout the tuning range. The radio-frequency losses in a receiver of

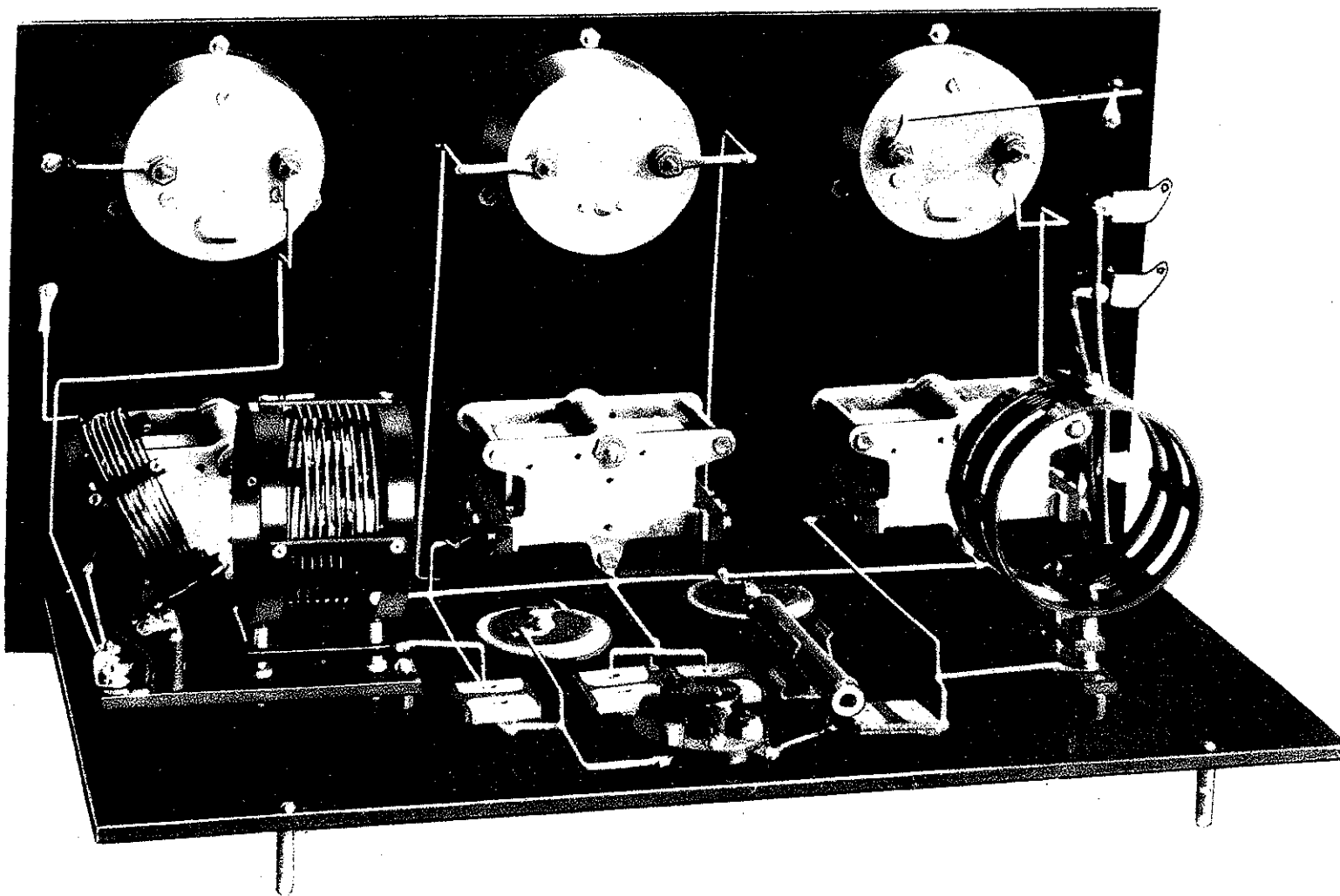


Figure 6

this type are much greater than when dealing with receivers operating on the higher wavelengths. A short wave set should be capable of oscillating over its entire tuning range, that is to say, there should be no non-oscillating points throughout the frequency spectrum covered by the receiver.

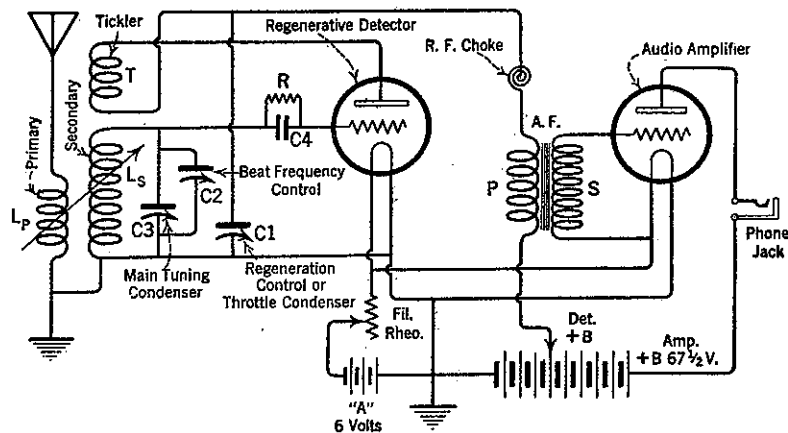


Figure 7

antenna, when connected to one of the plug-in antenna coupling coils, should be 300 meters, then, in this case the second harmonic would be 150 meters, the third harmonic 100 meters, the fourth 75 meters, and so on.

Accordingly it is possible to adjust an antenna, by using a certain coil, so that one of its harmonics falls approximately on the wavelength of the station whose signals are desired. If we adjust the coupling of the antenna coil and secondary coil too close when tuning a short wave receiver it would most likely cause oscillations to cease at the different harmonics. If this should happen the circuit can again be set into oscillation by increasing the regeneration which in this circumstance would be done by slightly decreasing the coupling. It will be found that stronger signals are obtained at these resonant points than on other wavelengths in the tuning range. A good plan to follow when tuning a set is not to plug the antenna coil in its socket until after other adjustments have been made as we have outlined in subsequent paragraphs. There is practically one standard type of receiver used in short wave reception. It employs a fixed tickler system, and a variable condenser (throttle condenser) to control the amount of regeneration. A diagram of a popular type short-wave receiver is shown in Figure 7.

Placing a Short Wave Receiver in Operation and General Description. The tuning and regeneration controls should be operated according to the suggestions given in the following paragraphs. These simple rules are applicable, in general, to any type of short wave receiver using a fixed tickler. Remember that efficient tuning comes only with practice. The best adjustments for receiving either telegraphic signals (code) or phone messages is a matter of experiment. A detector circuit consisting of a fixed tickler and a throttle condenser for regeneration control is used in our explanation. The schematic wiring diagram is given in Figure 7. Smooth regeneration control is effected by changes in the throttle condenser's capacity while tuning is but slightly effected by this method. In brief the function of this condenser is to limit the amount of radio-frequency current in the feed-back circuit, which is the same thing as saying that it limits the amount of regeneration.

Although the circuit shown in the diagram employs only one stage of a.f. amplification an additional stage may be added if desired; the connections then would follow the usual convention for such circuits.

The signal oscillations pass from the antenna system to the input circuit of the first tube by means of the mutual inductance (magnetic coupling) between antenna coil L_p and grid coil L_s . The grid coil and condenser C_3 comprise the tuned circuit and the r.f. voltage set up across condenser C_3 is applied between grid and filament. The maximum capacity of C_3 is .00025 mfd.

Regeneration is made possible through the fixed coupling between plate coil T and grid coil L_s but the actual amount of this regeneration is governed by the adjustment of the throttle condenser C_1 . It is the function of this condenser to limit the amount of radio-frequency current in the feed-back circuit. Changing this condenser's capacity causes it to offer more or less opposition to the high frequencies. The condenser's opposition is technically known as its reactance (capacity reactance). So when we say that a condenser offers more or less opposition to currents of different frequencies we could express

this in terms of reactance. However, it should be borne in mind that this condenser adjustment is not critical and, when once set, the circuit should oscillate over the tuning range without difficulty.

The tube should go in and out of oscillation slowly, not abruptly when changing from an oscillating to a non-oscillating conditions. When a short-wave receiver is first placed in operation both the wavelength and regeneration dials should be set at zero, followed by rotating the regeneration dial approximately one-third the distance across the dial scale until an indication of oscillation is heard in the telephone. A simple test which will indicate to you whether or not a receiver is oscillating is to touch the grid side of the secondary coil; if a click is heard in the telephones each time contact is made between your finger and condenser plate the receiver is oscillating. After reaching the critical point at which oscillation starts, the regeneration dial should be moved a few points higher for stable operation. Now after the above tuning adjustments have been made, plug in the antenna coupling coil with the antenna connected to the receiver. With the antenna coil separated from the secondary coil by about 2 inches as shown in Figure 6, you may find that the oscillations have stopped. In this case the regeneration dial should be again rotated a few degrees beyond this setting. If this is not sufficient to start the oscillations, a decrease of coupling between the antenna coil and secondary coil may be necessary. With the receiver oscillating, it will be found that when moving the wavelength dial from zero to maximum, the receiver stops oscillating at various points, indicating that the secondary circuit is in resonance with either the fundamental frequency of the antenna circuit or one of its harmonics. It is possible that the wavelengths most frequently used by the operator may fall on one of the non-oscillating points, and if this occurs it will be necessary to alter the size of the antenna, either lengthening or shortening it to permit oscillation to be maintained again. Reducing the coupling may also shift the non-oscillating dead points, but this in turn will decrease the signal strength. Also, by increasing regeneration to a higher point this undesirable condition may be overcome. In brief, there are two ways of shifting the dead spot to make the detector circuit oscillate over the entire range of the dial, either by inserting a coil or a condenser in series with the antenna, with a switch provided to cut these elements in or out as desired. Dead spots are often due to the use of inefficient choke coils in the detector plate lead. A choke coil with a very low impedance at certain frequencies in the short wave band will act as a short circuit for the tube's high frequency output and thus prevent the set oscillating. The obvious remedy in a case of this kind is the use of a good choke.

It may be necessary to alter the detector plate voltage, when interchanging plug-in inductances, for some require more voltage than others.

The short wave receiver illustrated in Figure 7 shows the plate coil T magnetically coupled to the secondary coil L_s , both coils being in a fixed mechanical relation, thus providing the requisite feed-back energy from the output to the input, as previously stated. The coupling between antenna coil L_p and secondary coil L_s is inductive and variable. The grid-leak resistance should be comparatively high, otherwise squealing and howling may occur, and the circuit in general be made unstable in operation. The correct value is found experimentally. We might suggest that the values of leak resistances, in general,

used for this work range from 2 to 10 megohms. Sometimes a leak resistance value of about 2 to 5 megohms will be found best while in other instances high values would be required.

The oscillatory circuit consists of the main tuning condenser C3 shunted across the secondary coil Ls. A variable condenser C2 of low capacitance is connected in shunt with C3 to provide a vernier control for fine tuning. Although each plug-in coil covers a large frequency range, the small variable air condenser C2 permits a close frequency variation which is called a beat frequency control. The regeneration or throttle condenser C1 connected between the filament and the tickler coil is adjusted whenever an increase or decrease in regeneration is desired. It functions as follows: The regeneration control or throttle condenser C1 should be held at a point where oscillations are just maintained when receiving CW or ICW. It will be found that the maximum response in the telephones will be received for a weak signal at this point, because, as set forth in one of our early lessons on the subject of regeneration, feeble currents are amplified in intensity a great many more times than a strong signal for the same adjustment of regeneration.

On the other hand, when it is desired to receive broadcasting, it is necessary to place the receiver in a non-oscillating condition, as previously stated. This can be done by adjusting the throttle condenser just below the point where oscillations are maintained, or at a point where the circuit is rendered incapable of producing oscillations, for this provides a maximum regeneration. In other words, the capacitance of C1 is varied until its reactance or opposition to the radio-frequency component of the plate current is sufficient to prevent oscillations and yet allows only a limited amount of energy to pass through; just enough in order to give maximum regenerative amplification. Adjustment of the filament current by the filament rheostat provides another method for obtaining maximum regeneration. This receiver functions as a straight regenerative circuit with feed-back provided by the plate coil, when it is not oscillating.

One stage of audio-frequency amplification may be added to the short-wave receiver as suggested in the diagram making it a two tube receiver, consisting of a regenerative detector and audio amplifier. This circuit functions similarly to any audio-frequency amplifier in building up a signal of satisfactory volume. The action of the audio amplifier, briefly, is as follows: An alternating e.m.f. is induced in the secondary of the audio-frequency transformer AF due to the changing magnetism set up about primary coil P. The grid of the audio amplifier tube is charged with this signal voltage. In turn the signal is repeated in the plate circuit by variations in plate current; such variations must faithfully record the audio wave form and the frequency of the input energy to the grid. This is the action of all amplifiers. The changing magnetism in the phone windings caused by the fluctuating plate current in the amplifiers output acts upon the diaphragms of the telephone receivers causing them to vibrate. To prevent the amplifier circuit from breaking into self-oscillation it is suggested that approximately 67.5 volts or less of "B" battery voltage be used on the plates, and the filament voltage carefully adjusted.

A radio-frequency choke coil is shown inserted in series with the detector

plate circuit to prevent losses of radio-frequency through the leads connecting to the power supply. In some short wave receivers, the r.f. choke coil is replaced by a high resistance of approximately 25,000 ohms. A radio-frequency choke coil can be easily constructed by closely winding 110 turns of No. 40 DCC wire in a single layer on a tubing of insulating material 2 inches long.

Winding data for six sets of plug-in inductances are tabulated herewith in order to suggest the approximate size of wire and number of turns necessary for the coverage of given wavelength bands. The corresponding frequency range is also given. Only an approximation can be given because the tuning range is governed by the capacity of the tuning condenser used, as we have stated before.

The range of wavelengths which certain coils will cover depends mainly upon the maximum capacity of the tuning condenser shunted across the coil. To give you some idea of the wide variance in the relation between the capacity and coil versus wavelength band we have set forth in the paragraph following below a few cases for comparison.

The inductances are made up in different forms according to the preferences of a designer. We have the solenoid type, sometimes referred to as the single layer wound, the basket weave type, etc. All coils are designed with the view of lowering their distributed capacity to prevent high frequency losses. Basket weave or Lorenze coils have a low distributed capacity but there is a slightly smaller magnetic field built up around these coils on account of the space winding, than is the case in layer wound coils.

It should be remembered that the range of wavelengths which certain coils will cover depends upon the maximum capacity of the tuning condenser which is shunted across it.

Other refinements may be included, such as a movable tickler coil to be used principally for initial adjustments. The rotary condenser plates should connect to the filament side of the circuit in order to cut down the body capacity effect, and grounding of the filament circuit may be necessary in some cases.

The plug-in inductances generally used with short wave receivers are of the flat layer solenoid type, wound on notched rib forms, or narrow bars of high grade insulating material. The basket weave (Lorenze) type is another form of winding in wide use, its particular form gives it mechanical strength, and because it is self-supporting it requires only the use of an insulated bar to hold the terminal pins for making electrical connection to the jack plugs.

Some idea of this dependence of frequency range upon the size of a coil and the capacitance associated with it can be obtained if we cite but a few examples as follows: The values given are only with the understanding that they will differ when various types of coils are used in the receiver, as for example, the solenoid or single layer wound coil, basket weave and other popular types.

WIRE DATA FOR PLUG-IN INDUCTANCE COILS

Coil :	Frequency Band :	Corresponding Wavelength Band :	No. of Turns on the Tickler :	No. of Turns on the Primary :	No. of Turns on the Secondary :
:	Kilocycles :	Meters :	:	:	:
1 :	1000- 2150	300 - 139	6	4	33
2 :	2150- 4550	139 - 65	4	3	18
3 :	4550- 7300	65 - 41	4	2	10
4 :	7300-11000	41 - 27	4	2	8
5 :	11000-16000	27 - 17	4	2	6
6 :	16000-20000	17 - 15	3	1	4

An enameled No. 28 wire is used for the tickler and primary windings, and No. 20 wire for the secondary of all coils. The turns are space-wound to lower their distributed capacitance and are wound on a form 3 inches in diameter.

The receiving circuit just described is known as a regenerative detector circuit with one stage of audio amplification, and is practically standard for short-wave work. A vacuum tube circuit used solely as a combined detector, oscillator and amplifier is known generally as an "autodyne" circuit.

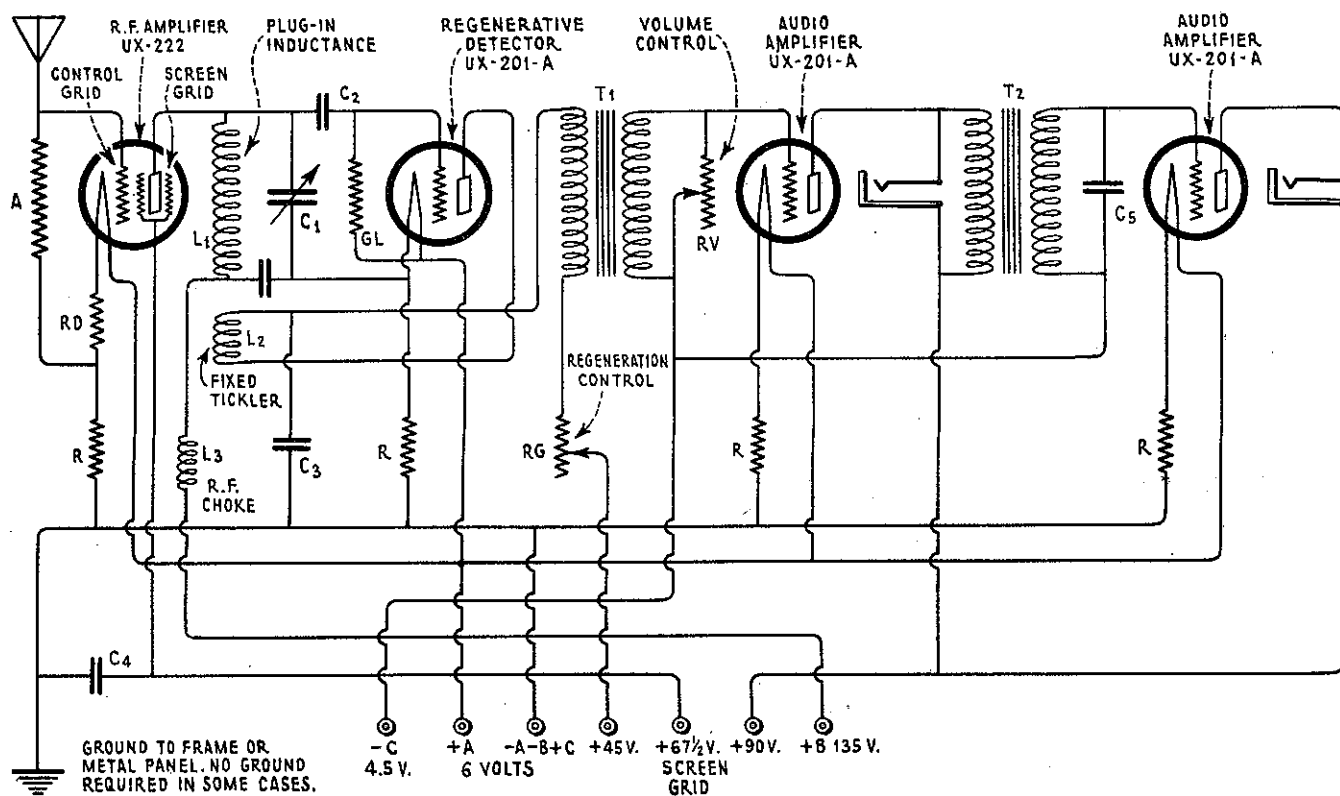


Figure 8

A schematic diagram and circuit constants of a four tube set employing the screen grid tube in the r.f. stage is given in Figure 8. You will immediately recognize that the regenerative detector circuit is arranged similar to the

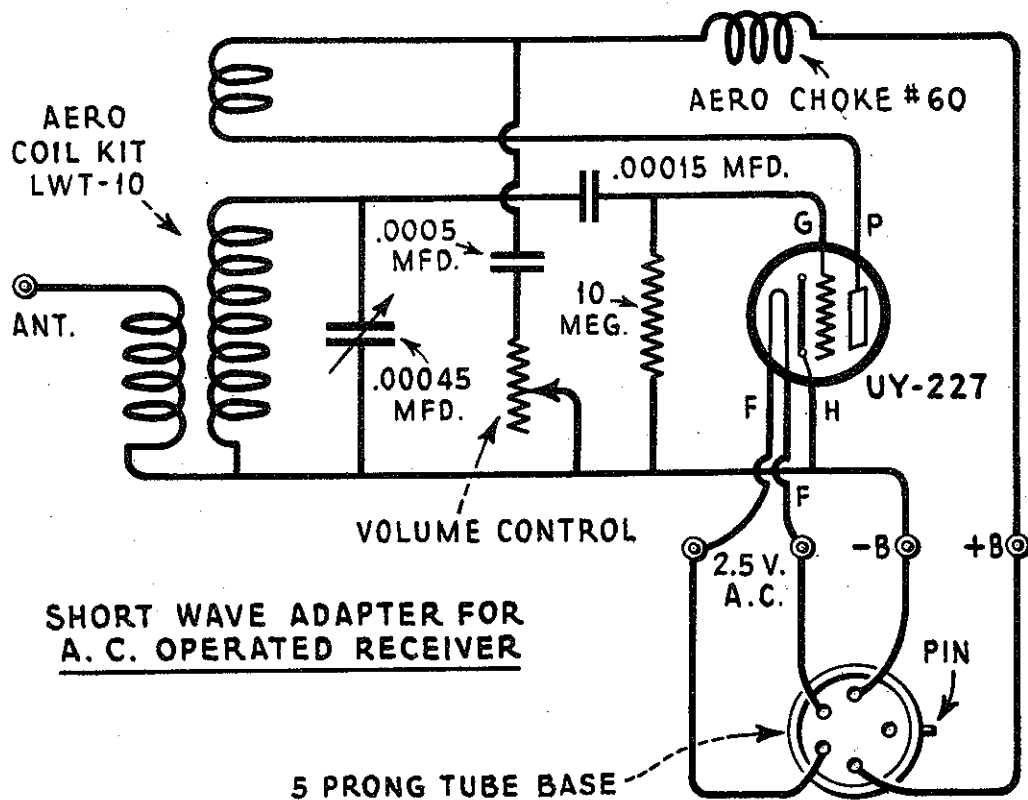
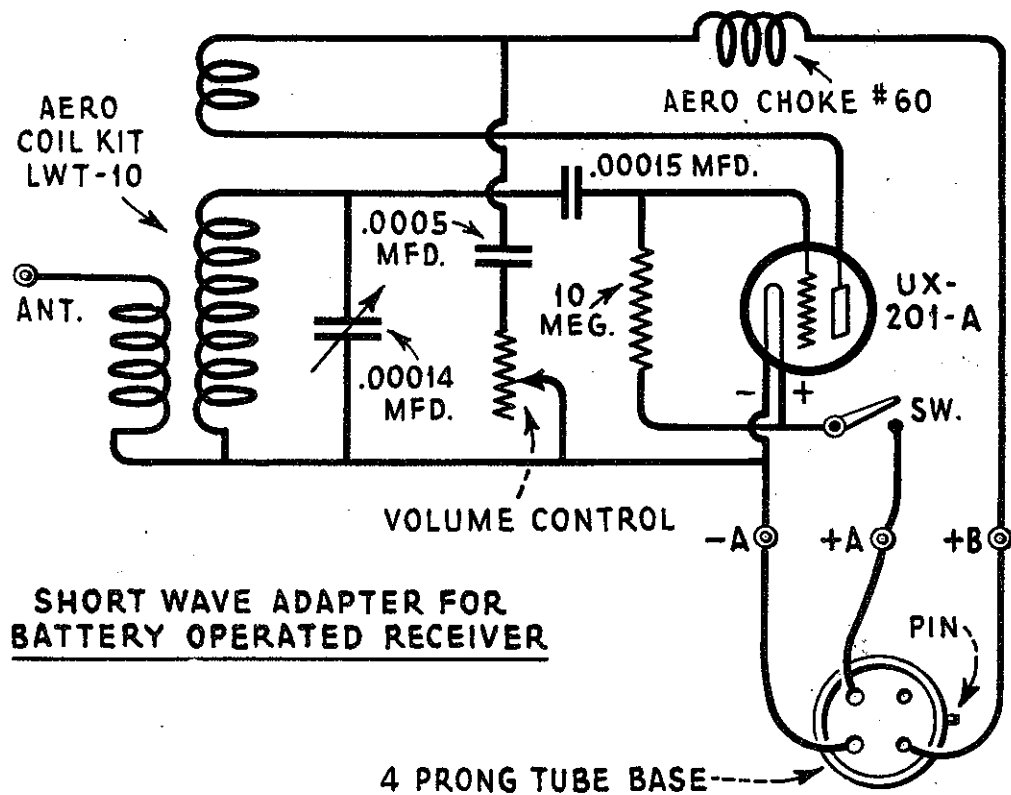
circuit shown in Figure 2. The addition of a radio-frequency stage and two audio stages does not materially alter the principles involved in the use of the regenerative detector.

A short wave set may be coupled to a special audio amplifying system to work in conjunction with a televisior for the reception and reproduction of moving objects and scenes. It requires a broad band of frequencies to accomplish television and for this class of service special channels must be allocated by the Radio Commission. The modulating frequencies used in this work may include in some instances a band between 80 to 500 kc. in width. In general the number of "dots" to each picture and the number of complete pictures transmitted each second determine the perfection of definition of the image reproduced by the receiving set.

Antenna. An outdoor antenna of most any shape or dimensions will pick up sufficient energy to give good readable signals in the 20 - 40 - 80 - meter and other short wave bands. A vertical antenna is not considered as efficient as one having both horizontal and vertical positions. Whenever local conditions permit it is a good plan to elevate the aerial wire as high as possible in a free unobstructed space, and clear of all energy absorbing bodies. The length of the wire is not critical and in most installations you would find that a wire from about 20 to 60 feet would prove sufficient for this purpose. A long antenna for short wave work is not necessary. Insulators having a high dielectric strength, such as glass insulators, reduce high-frequency losses and should be used at all points of support.

Legend and Circuit Constants for Receiver shown in Figure 8.

- A Antenna Coil. The incoming signal current sets up a voltage drop across "A" which is applied between grid and filament of the r.f. amplifier. This coil is of the plug-in type.
- L1 Tuning Inductance - Plug-in type.
- L2 Tickler Inductance - Plug-in type.
- L3 R.F. Choke. A choke suitable for short wave work should range in inductance value from approximately 85 to 250 millihenries.
- C1 Short Wave Variable Tuning Condenser - Plug-in type optional. Generally called a midget condenser. If not of the plug-in type (i.e., the condenser is permanently wired in) then usually its maximum capacity should be about .00015 mfd.
- C2 Grid condenser - .000100 to .000150 mfd.
- C3 Fixed By-pass condenser 2000 mmfd (.002 mfd.)
- C4 Fixed By-pass condenser .003 mfd. (3000 mmfd.)
- C5 Fixed By-pass condenser .0005 mfd (500 mmfd.)
or .001 mfd (1000 mmfd.)



RRRR Filament ballast resistors of .25 ampere type used to automatically regulate the filament voltage. (This value depends upon the type tube)

RG Regeneration Control. Variable resistance 50,000 ohms.

RV Volume Control. Variable resistance 200,000 ohms.

RD Biasing Resistor of from 10 to 15 ohms. Furnishes a small bias to the control grid of the Four-electrode tube UX-222.

GL Grid Leak Resistance. From 2 to 10 megohms.

T1 & T2 High grade audio transformers.

EXAMINATION - LESSON 64

1. What is thought to be the cause of the skip distance phenomenon experienced in high frequency transmission and reception?
2. How many adjustable condensers are used in the average type of short wave receiver? Briefly, what purpose does each one fulfill in the set?
3. Of what advantage is a coil-condenser combination of the plug-in type?
4. Draw schematic diagrams showing two methods commonly used for the control of regeneration.
5. What wavelengths would you include in the short wave and long wave bands?
6. What does the table of values given on sheet 6 indicate to you?
7. Given a distance 3500 miles find the frequency to produce a good readable signal at the distant receiving station? Is your answer absolutely correct for all conditions?
8. (a) Is there any advantages to be gained by harmonic tuning? Give reasons. (b) Why is magnetic coupling between the antenna coil and the grid coil usually employed in short wave sets?
9. State as many points as you can think of in the placing of a set in operation and tuning. Answer this as though you were giving instructions in the operation of an average type short wave circuit.
10. (a) Why is a smooth control of regeneration essential in circuits of this type? (b) Draw a schematic diagram of a four tube receiver employing the screen grid type tube for the r.f. amplifier.